

INVESTIGATION OF ASPHALT PAVEMENT SLIPPAGE FAILURES ON
RUNWAY 4R-22L, NEWARK INTERNATIONAL AIRPORT

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ABSTRACT

Aeronautical asphalt pavement are susceptible to slippage failures especially on runways at the high-speed taxiway exits, as airplanes brake and turn. Plastic deformation of asphalt usually occurs under loading at high ambient temperatures. To combat this problem asphalt mixes are polymer modified and their aggregate skeletons are designed to have sufficient stone-to-stone contact for adequate structural integrity. The top pavement lift should also provide enough depth for the shear forces to dissipate. Polymer modified asphalt cements, sound aggregate skeletons and the use of textured sands have produced mixes capable of transferring loads to the subbase. However, smoothness criteria outlined in FAA specifications have tight tolerances, which drive the contractor into constructing the pavement with multiple thinner lifts rather than fewer thicker lifts. This allows more opportunities to correct deficiencies as the pavement structure is built to finished grade. The drawback to this method is the multiple layers that comprise the depth of the pavement may not act as one solid unit under shear forces. Precautions are taken to avoid this by treating the surfaces at the interface by cleaning the surfaces of dust and debris and applying a tack coat prior to overlay. In addition to this, there must be some degree of aggregate interlock between lifts provided by protrusions of aggregates of the overlay into the layer below. This happens during the rolling operation and is facilitated through heat transfer. The aggregates that penetrate into the underlying layer act as shear studs, which aid in preventing slippage at the interface of the first and second lifts when undergoing shear and torsion forces. The aggregates however, must have enough strength not to shear themselves.

INTRODUCTION

Runway 4R-22L at Newark International Airport, which is primarily a landing Runway, had experienced slippage at the interface of the first and second layer of asphalt in the keel section approaching high-speed Taxiway 'N'. A visual inspection performed in September of 2005 revealed displaced grooves in this area, which appear to be a symptom of heavy braking and shear forces induced by the airplanes as they land and exit the Runway via high speed Taxiway 'N', during the summer. Investigative cores obtained show no indication of failure within the asphalt mix itself, rather a lack of bond at the interface of the first and second lift causing the top layer to slide (Figure 1). It is important to note that during the summer months, airplanes land in the north to south direction which facilitates traffic onto high-speed taxiway 'N'. During the winter months, *when the pavement is stiffer*, the airplanes land in the south to north direction in which the corresponding high-speed taxiways show no signs of slippage.

Two sources of stone were supplied for the most recent rehabilitation of the asphalt pavement for Runway 4R-22L which took place in 2004: Granitic-Gneiss and Traprock. Although both sources exist in the vicinity of the areas in question, only the Granitic-Gneiss is exhibiting slippage failures. The preceding rehabilitation took place in 1997 in which the material was comprised completely of granitic-gneiss. A visual inspection in 2002 showed slippage failures in the same location near high-speed taxiway 'N'.

The theory of inadequate tack coat or poor band at the interface as a possible culprit for movement in 2005 was ruled out due to the slippage taking place only in the lanes in which the top lift was granetic-gniess. The traprock, although in the vicinity and subjected to the same shear and torsion forces, remained virtually undisturbed.

Visual inspections of all remaining Port Authority runways and corresponding taxiways have been performed to learn of other possible slippage failures. The standard battery of tests were performed within the slippage failure areas approaching high-speed taxiway 'N' in 2005 for in-place air voids (ASTM D-2041, D-2726 & D3203) and viscosities (ASTM D-2172) to rule out any premature conclusions that the problem is aggregate source related. Low in-place air voids would indicate a high possibility of plastic deformation under high temperatures. If the viscosities were lower than expected the same could happen as well as the asphalt binder at the interface becoming plastic and acting as a lubricant, aiding in the sliding of the top layer with respect to the second. This would be more likely to occur if the asphalt binder content was too high. This paper presents the results of the laboratory study into the interface shear resistance between layers containing Granetic-Gniess and Traprock.

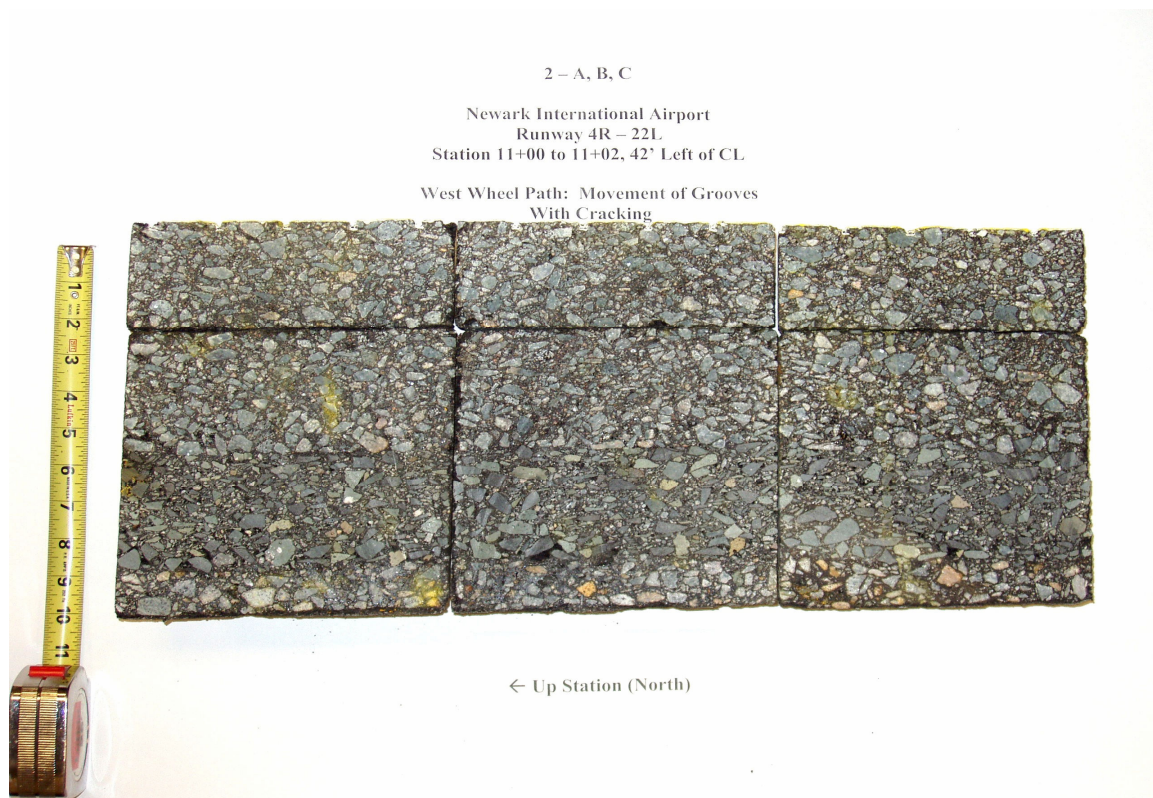


Figure 1. Asphalt Layer Cores from Slippage Areas.

LABORATORY PERFORMANCE EVALUATION OF ASPHALT PAVEMENT INTERLAYER BOND STRENGTH

First, the areas containing slippage were cored and evaluated for viscosity, in-place air voids and gradations. These are three basic fundamental characteristics, which describe the overall strength and stability of an asphalt mix. Table 1 shows representative cores taken from the slippage area in both the current asphalt pavement (Contract EWR 154.337) as well as the previous (Contract EWR 653). All investigative cores done under EWR 653 take into account the top lift only.

Table 1.
Material Characteristics of Collected Cores from EWR 653.

Core No.	26	27	2-B ₁	2-B ₂	
Contract	EWR 653	EWR 653	EWR 154.337	EWR 154.337	
Gradation					Specifications
1"	100.0	100.0	100.0	100.0	
3/4"	99.3	98.1	100.0	100.0	
1/2"	94.4	92.1	92.1	94.9	72.0 - 98.0
3/8"	82.8	80.6	79.4	82.7	60.0 - 82.0
#4	44.6	46.9	51.6	51.2	40.0 - 56.0
#8	30.4	30.5	36.1	35.5	28.0 - 39.0
#16	21.7	22	25.5	24.6	19.0 - 24.0
#30	15.7	16	17.5	16.7	13.0 - 19.0
#50	10.9	11.2	11.9	11.3	8.0 - 16.0
#100	7	7.3	7.9	7.6	5.0 - 10.0
#200	4.2	4.6	5.4	5.2	3.0 - 6.0
AC Content	4.95	5.03	5.22	5.51	5.0 - 6.0
In-Place Air Voids	4	4.3	4.9	6.7	
Lift	1st	1st	1st	2nd	
Thickness	3.5"	3.5"	2-7/8"	2-3/4"	
Visc @ 140o F (Poises)	27,681		10,954	12,318	

As illustrated in Figures 2 through 7, the majority of the stresses causing the slippage failures take place in the same general location. However under contract EWR 154.337 in which Traprock was supplied as well, the slippage failures are contained within the paving lane width comprised of granetic-gniess. On EWR 653 (Figure 6), the diagram shows that the slippage failures are more widespread into adjacent lanes which are comprised of granetic-gniess as well.

The core samples taken from the field were cut so their cross sections could be viewed. The mix itself appeared stable while there was no bond at the interface of the first and second lift. The interfaces had drag marks on them and were lightly coated with sheared pieces of granetic-gniess (Figure 8). Upon finding no conclusive evidence from the testing thus far as to the cause of the slippage failures, and the fact that these failures took place in the same area twice without affecting areas containing traprock, a more in depth investigation was needed.

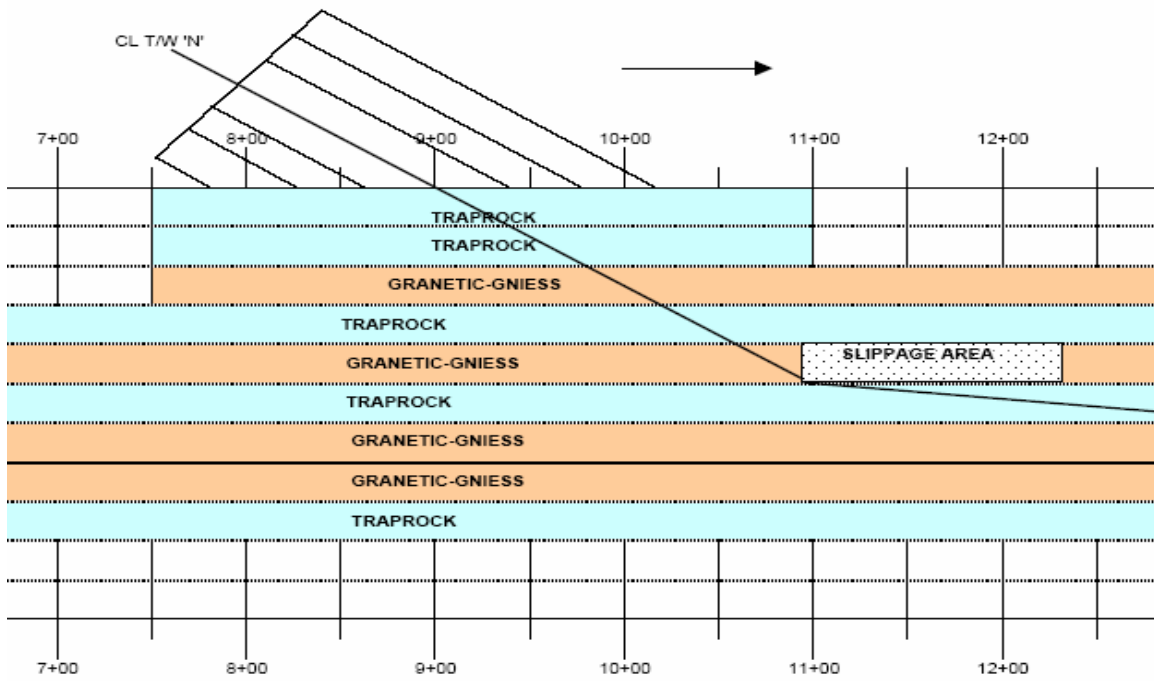


Figure 2 – EWR 154.337 – Top Lift Paving Diagram Showing Aggregate-Type (Top View)

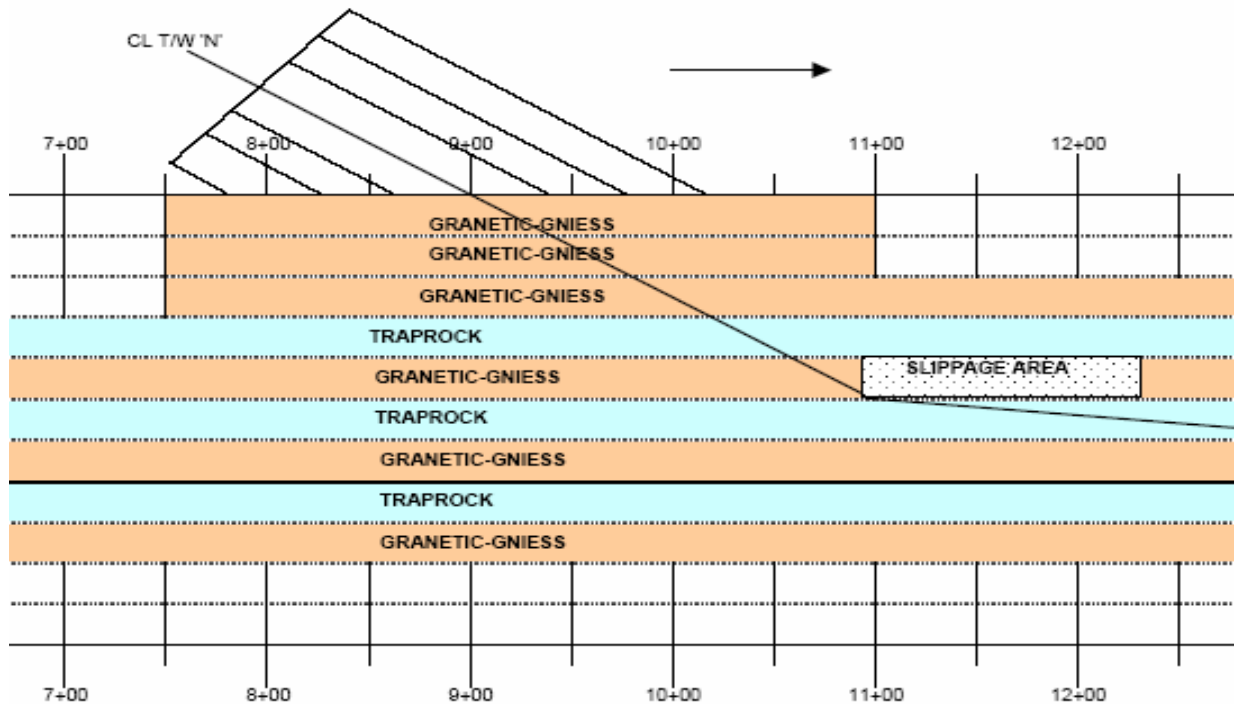


Figure 3 – EWR 154.337 – Bottom Lift Paving Diagram Showing Aggregate Type (Top View)

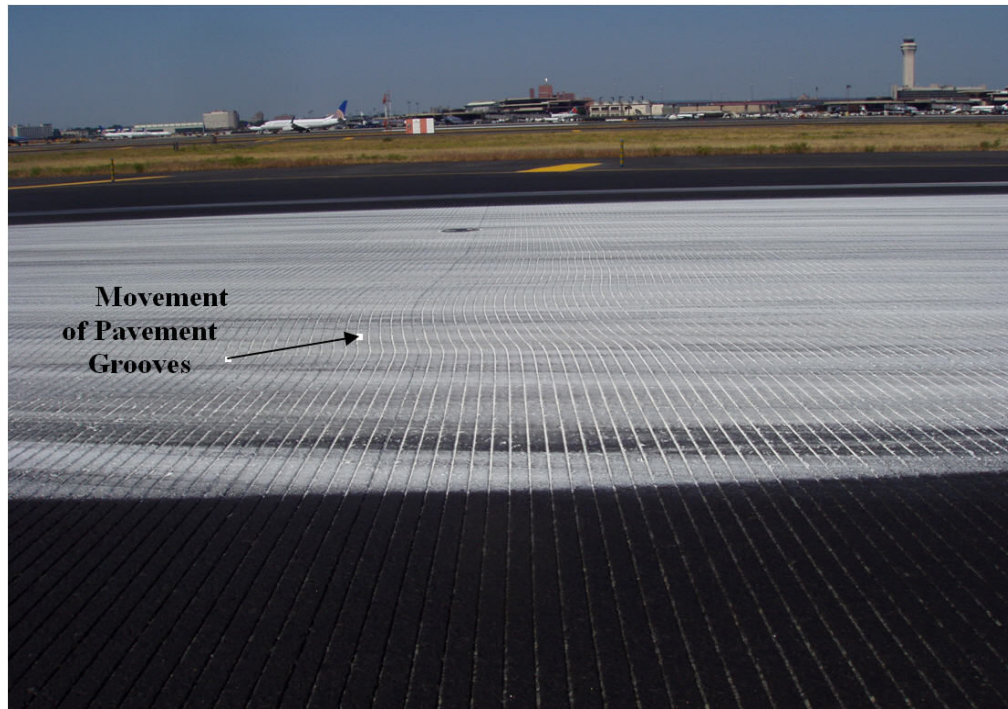


Figure 4. Slippage at High-Speed Taxiway 'N' Under Contract EWR 154.337 (Note "Curved" Grooves Indicating Slippage).



Figure 5. Slippage Observed at Longitudinal Joint (Left of the Vertical Stripe is Traprock; Right is Granetic-Gniess).

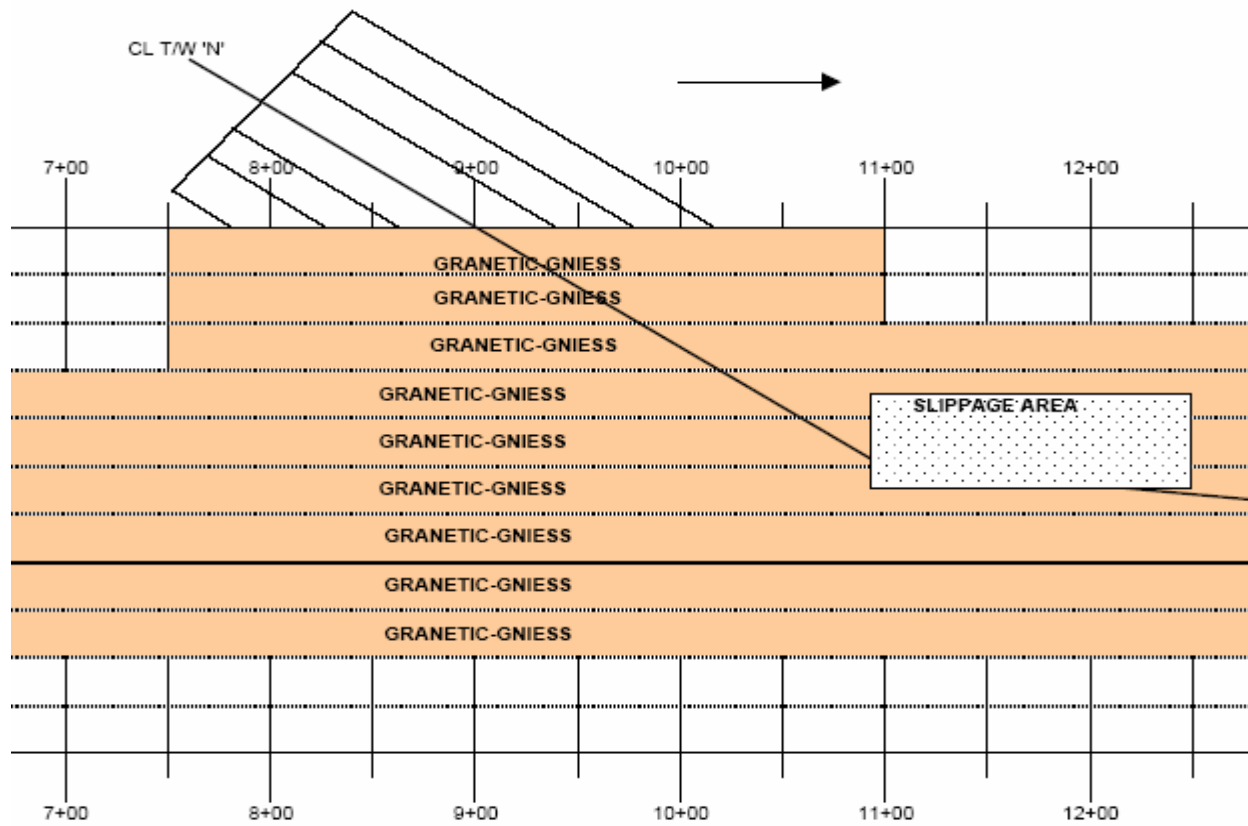


Figure 6. EWR 653 – Top Lift Paving Diagram Showing Aggregate Type (Top View).



Figure 7. Slippage at High-Speed Taxiway 'N' under Contract EWR 653.



Figure 8. Interface of Pavement Lifts from Both the Stable (Left) and Slippage (Right) Areas.

LABORATORY TEST TO SIMULATE SLIPPAGE POTENTIAL

In the past, the bond strength of the interlayer has been typically measured using a static, guillotine-type of shear fixture used to measure ultimate bond strength (Figure 9). Although recent work with this type of test has been recently used by a number of researchers to evaluate optimum tack coat types and application rates [1, 2, 3], the static loading condition utilized does not model the cyclic nature of pavement/airfield loading conditions. To better simulate the loading conditions, a dynamic “pulse-load” test would be preferred over the static strength test. The test method should be able to apply cyclic loading in both the vertical and shear directions, as would occur in the field.

The Superpave Shear Tester (SST) is a bi-axial loading device that provides both dynamic shear and axial loading (normal stress or confining stress) to the HMA sample simultaneously (Figure 10). Although the SST is typically conducted under a “Constant Height” mode (AASHTO T320) to allow HMA samples to develop natural confining pressures during sample dilation, the proposed method is using the “Constant Stress Ratio” to potentially allow the change in sample height when a failed interface allows the top and bottom lifts to slide over top of each other.

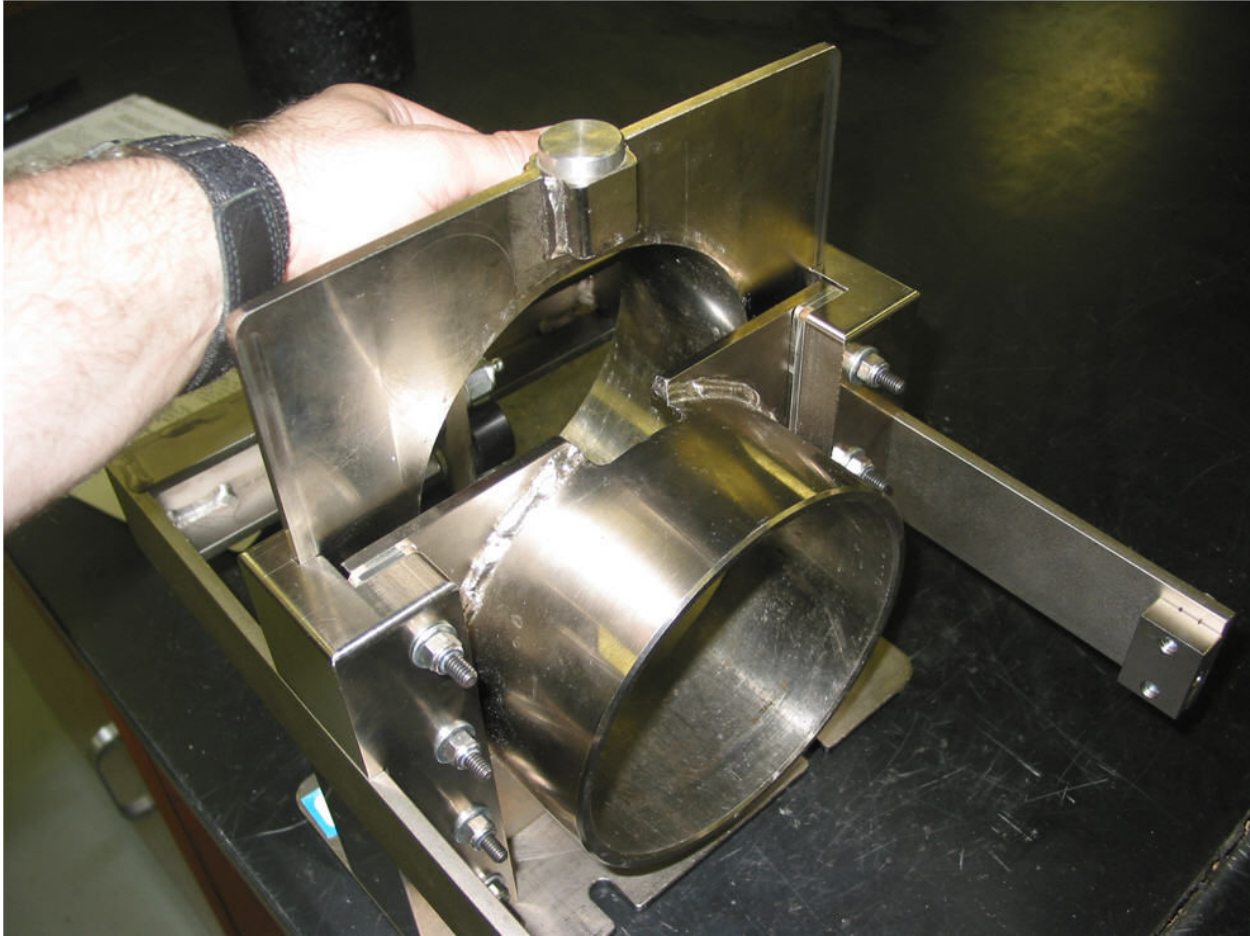


Figure 9. Tack Coat Shear Mold Used by NCAT (Provided by West et al., 2005).

To evaluate if the test procedure could produce valuable information, HMA samples were produced in the laboratory and tested under various stress ratios and test temperatures. To produce the interface samples, a 50 mm HMA sample was first compacted in the gyratory mold and allowed to cool overnight while remaining in the mold. The following day, loose mix was placed in the mold directly over the first compacted lift and again compacted to 50 mm. After the extruded “interface” sample had cooled, 25 mm was cut off of both ends to provide a final SST sample of 50 mm thick. Initial test specimens were produced using a 12.5mm Superpave mix with a PG76-22 asphalt binder that was sampled during a rehabilitation project for the NJDOT.

Figure 11 shows an example of some of the initial testing. As can be seen from Figure 11, there is a distinct change in the slope of the vertical strain and shear strain at approximately 700 test cycles. The initial slopes of both the shear and axial strain represent the aggregates at the interface moving until a solid interlock is reached. The downward slope moves towards a minimum plateau at which debonding initiates. Once debonding has initiated, the slopes of both deformations increases steadily and is indicative of the aggregates sliding over each other.

Final test parameters that were evaluated and recommended for further evaluation with the Granitic-Gneiss and Trap Rock field cores were:

- Test Temperature = 100°F
- Cyclic Stress Ratio = 1.25 (Vertical Stress = 18.75 psi; Horizontal Stress = 15 psi)
- Applied Pulse Load = 2 Hz (0.5 seconds)
- Rest Period Between Applied Loads = 1 second

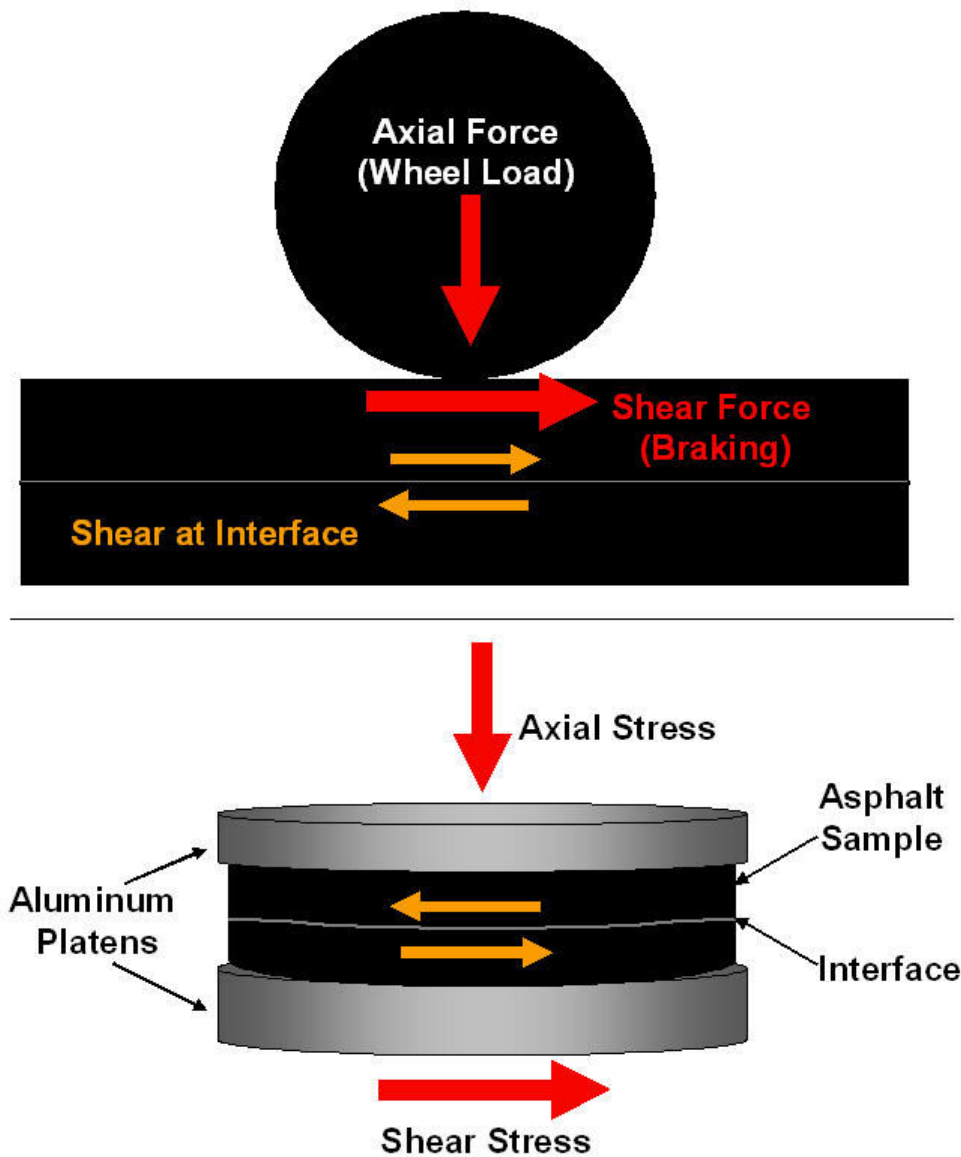


Figure 10. Idealized Comparison Between Field Loading and Laboratory Loading.

SLIPPAGE POTENTIAL TESTING OF FIELD CORES

Stable core samples were obtained of the first and second layers of granitic-gneiss and traprock in areas outside of the traveled keel section located in close proximity to each other. The cores are from lots produced on the same day and have similar properties in order to compare shear resistance potential. The bulk, maximum specific gravities and in-place voids of the specimens obtained are shown in Table 2 and illustrate the volumetric similarities between the two mixtures. Table 3 contains uncompacted void content for the fine aggregate in accordance with AASHTO T304 Method A, and the coarse aggregate void data, loose and rodded weights in accordance with AASHTO T19.

Using the proposed test parameters and the sudden change in the shear and vertical strains to identify the number of load cycles until slippage occurs, a comparison of the three Granitic-Gneiss samples shows that the interface bond broke between 2,800 and 4,450 cycles, with an average of 3,384 loading cycles until the interface bond breaks. A typical plot of the test results of the Granitic-Gneiss samples is shown as Figure 12. The plot clearly shows the sudden change in both the shear and vertical strains.

Table 2.
Bulk and Maximum Specific Gravity Properties of the Specimens.

Sample No.	Bulk Specific Gravity, g/cm^3	Maximum Specific Gravity, g/cm^3	Air Voids, %
Trap Rock #3	2.471	2.571*	3.9
Trap Rock #4	2.472	2.571*	3.8
Trap Rock #5	2.459	2.571*	4.3
Trap Rock Average =			4.0
Granite/Gneiss #1	2.456	2.551*	3.7
Granite/Gneiss #2	2.472	2.551*	3.1
Granite/Gneiss #3	2.463	2.551*	3.5
Granite/Gneiss Average =			3.4

*Indicates that an average G_{mm} was used based on HMA of the cores tested

Table 3.
Angularity Indexing of Aggregates.

Fine Aggregate Angularity (AASHTO T304, Method A)			
Aggregate Type		Uncompacted Void Content, %	
Granitic-Gneiss ¹		45.2	
Trap Rock ¹		46.6	
Loose and Rodded Weights (AASHTO T19)			
		Air Voids, %	
Aggregate Type	Coarse Fraction Size	Loose	Rodded
Granitic-Gneiss ²	5/8 in.	47.7	41.1
Granitic-Gneiss ²	3/8 in.	50.9	45.2
Trap Rock ²	5/8 in.	50.1	44.1
Trap Rock ²	3/8 in.	51.4	46.2

¹Aggregates from sampled cores

²Aggregates sampled from cold bins

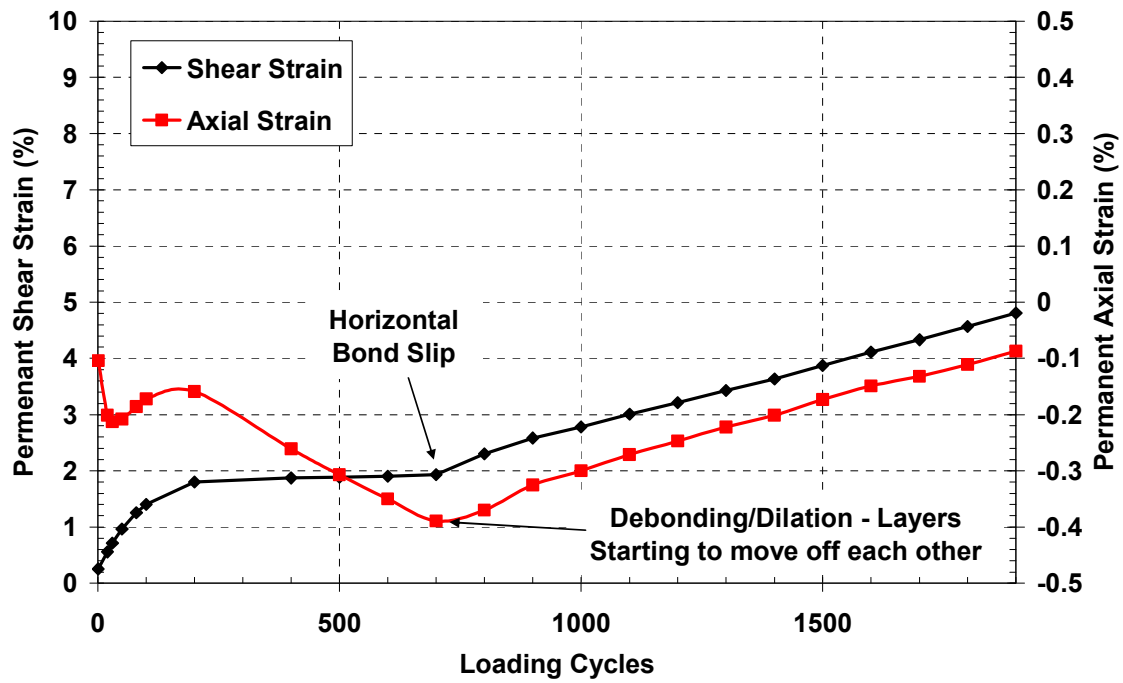


Figure 11. Example of SST Constant Stress Ratio Testing During Test Procedure Development.

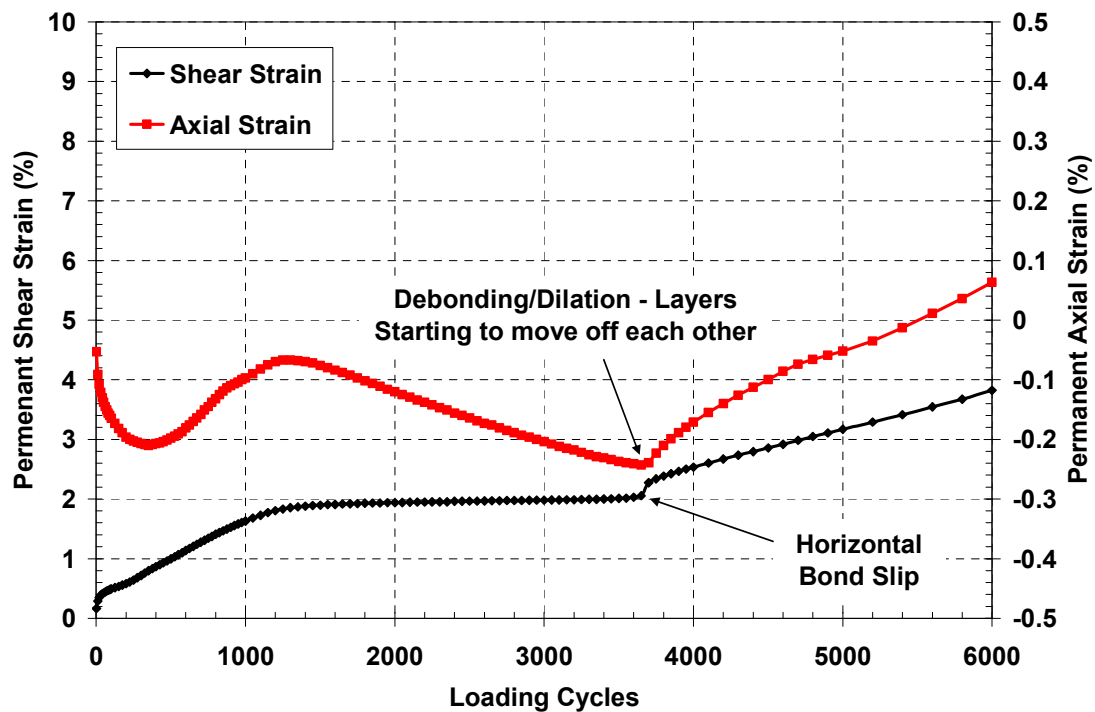


Figure 12. Typical Plot of Granitic-Gneiss Samples.

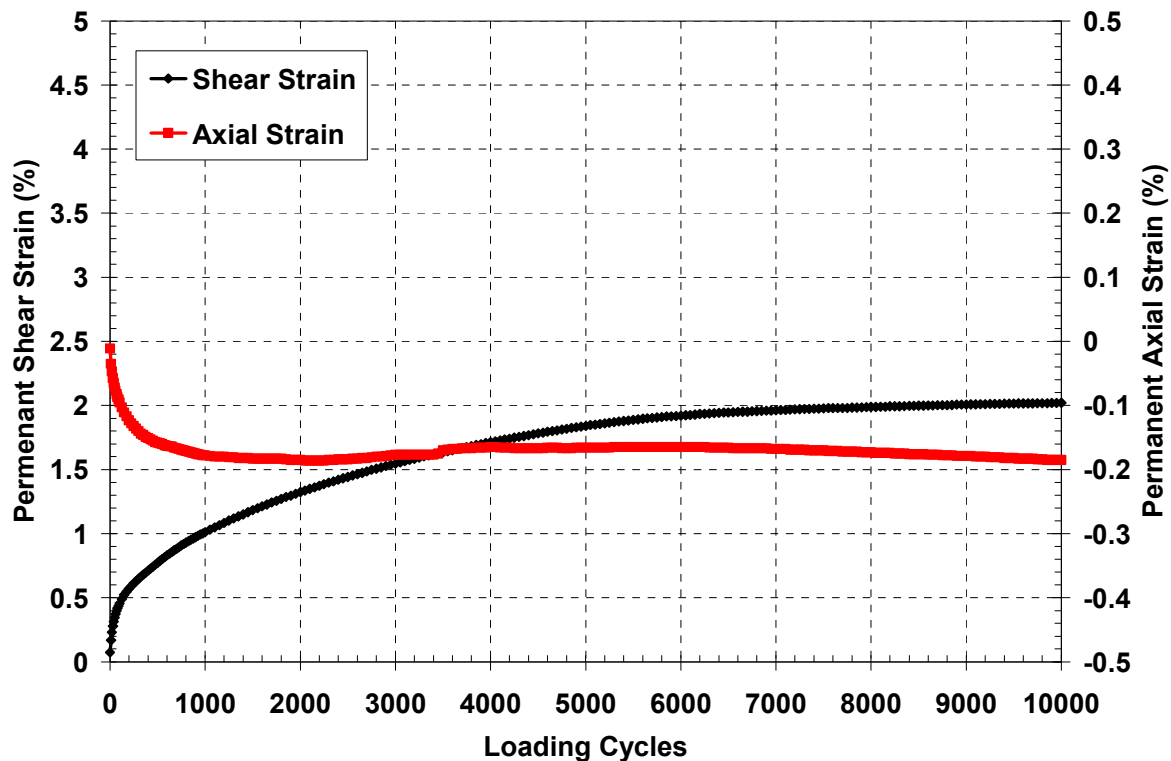


Figure 13. Typical Plot of Trap Rock Samples.

When evaluating the same performance curves for the Trap Rock aggregate samples, there was no indication that a bond had been broken. Figure 13 shows a typical plot of the Trap Rock samples. In fact, the Trap Rock samples perform in an identical manner to HMA samples that do not have a bonded interface. This indicates a strong interface bond where the two HMA lifts perform in a manner that would represent one single layer in the field.

CONCLUSIONS / RECOMMENDATIONS

Testing for fundamental properties did not provide any information as to why paving lanes comprised of Granetic-Gneiss were experiencing slippage failures and not the Trap Rock, although both are subjected to the same shear and torsion forces. The test procedure developed using the Superpave Shear Tester (SST) differentiated between the two types of stones while the HMA fundamental properties held constant.

It is recommended that Granetic-Gneiss not be used for high-speed taxiways in the areas subjected to heavy braking and torsion due to this material not providing a sufficient amount of aggregate interlock. Further research needs to be done to determine whether Granetic-Gneiss could be used in this application if the surface of the underlying lift is scarified perpendicular to the direction of traffic, which would provide additional mechanical interlock. The PANYNJ Materials Division will be looking into using a milling machine in the transverse direction prior

to place of the top lift, to provide sufficient mechanical bond. Future work using the SST test procedure on milled and un-milled surfaces are also planned.

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